4.3.6   Urban Weather

The weather in urban environments is more challenging to characterize than weather in other environments. Urban environment induced micro-climates can cause sharp changes in wind speed and directions at the scales of meters. Urban heat island effects can enhance thermal activity and cause notable up and down drafts, and changes in density altitude between downtown districts and airports in the suburbs or near large bodies of water. Both modeling and measuring current conditions in these micro-climates required higher-density weather and wind measurements than commonly deployed for traditional aviation operations. To achieve an adequate degree of weather resiliency to contribute to reliable and cost-effective UML-4 operations a combination of airframe airworthiness improvements, smart siting of vertiports and a reduction in weather and wind uncertainty caused by urban weather is required. The weather operations structure in UML-4 is a combination of policy, reporting on current weather conditions, forecasting future weather conditions and information distribution and decision making. Arriving at this structure was the result of work by the FAA, NWS, NASA, DOD, the NSF's NCAR, Standards Groups such as ASTM, industry, trade groups and universities.

4.3.6.1 Policy and Regulations

The weather policy at UML-4 evolved from requiring the vehicle operator or pilot to be responsible for the quality of the weather information to the weather data provider. The vehicle operator is still responsible for becoming familiar with all available information concerning the flight, but at UML-4 standards have been updated or created for weather data performance for government weather service providers and Weather Supplemental Data Service Providers (SDSPs) and weather data interface standards. Operators and aircraft are still responsible to maintain weather awareness and recognize hazardous weather situations and implement appropriate procedures for inadvertent flight into hazardous weather or operating in hazardous weather in case of emergency. Weather related standards are largely performance based mitigating the need for new standards development for each new vehicle configuration.

Determining the parameters for defining hazardous weather is a process of continuous refinement between the vehicle manufacturers, vehicle and vertiport operators, entities providing weather services, and the FAA. Vehicle manufacturers provide the vehicle operating envelope e.g. control authority in cross-winds, icing conditions and performance impacts due to operating temperatures, etc. The vehicle operator provides envelopes for desired passenger comfort e.g. acceptable rates of sudden descent in turbulent or wind shear conditions, the vertiport operator conditions that would require the closing of one or more of the landing/takeoff spots e.g., dangerous building wake turbulence conditions. Weather service providers disseminate notifications of current or forecast hazardous weather informed by FAA and community weather related safety requirements along with decision support tools (DST) utilizing this weather information to inform the vehicle and vertiport operators when hazardous weather thresholds will be met or exceeded. At UML-4 the FAA, in collaboration with the community provided the foundational definitions of hazardous weather conditions, but SDSPs provide tailored and flexible products to serve operators that have more stringent requirements for weather services for specific vehicle types.

Weather data is also critical for airspace management and deconfliction decisions. By UML-4 policy has been developed that guides vehicle separation requirements in areas of high-density operations that

considered Instrument Meteorological Conditions (IMC), wake turbulence and the potential impacts of strong winds aloft and the up and downdraft conditions associated with thermals and wind flows around obstacles. The process continues as vehicle capabilities improve, passengers become more seasoned and weather forecasting and DSTs become more refined.

4.3.6.2 Weather Data Collection

Creating a robust UML-4 common weather operating picture includes the collection of current weather information. As mentioned above, urban environments are challenging because manmade structures can create sudden changes in wind speed and direction both around buildings and as a result of thermal updrafts over dark surfaces such as parking lots and thermal downdrafts over cooler surfaces such as parks. Urban environments can range from a few degrees to 10 degrees or more warmer than rural locations and regional airports. They are influenced by the same general weather patterns that impact the region, but are subject to the manmade structures that make adequate weather data collection coverage a challenge and unique to each city. Solving this challenge in weather data collection required balancing the need for greater granularity of weather observations, at a micro-climate scale, with the cost of taking those observations.

At UML-4 observations are taken using a layered approach with multiple types of sensors and sources. Three of the layers are described here. There are fixed, specialized weather sensing infrastructure, weather data being generated by sensors aboard sUAS and UAM vehicles and Internet-of-Thing (IoT) weather data sets utilizing sources such as traffic and other cameras, car temperature sensors, home weather systems, etc. The fixed sensing infrastructure provides a foundational capability designed with several features not available in mobile sensors. It provides assured data sets when vehicles are not flying and supports calibration and validation of the other data sources. This specialized weather infrastructure accommodates areas where higher quality data is needed such as near vertiports, in high density routes and around high rises. IoT data sets allow for higher density measurements and is scalable at an affordable cost while also closing situational awareness gaps that more expensive measurement infrastructure cannot fill.

Weather data collection to increase measurement density and scalability at UML-4, considered how to incentivize private sector companies, municipalities and state governments to install weather sensing equipment and receive payment for the data that allows for data purchases by government and commercial Weather Supplemental Data Service Providers to improve UML-4 weather situational awareness and predictions.

4.3.6.3 Weather Data

Weather data meeting performance standards, collected from sensors described above, will be accessible from government, private sector (e.g., Weather Supplemental Data Service Providers) and non-profit entities following a standard set of data performance standards Policies for data sharing will have determined the availability of data from privately owned sUAS and UAM vehicles. It was recognized that data made available for the public good in supporting departments of transportation and research was desirable and incorporated into these policies. While local data sources across the country have a similar structure based upon weather data interface standards, the funding model for the availability and maintenance of this data varies across entities participating in UAM operations.

Options include public funding, a credit system for providing data and then receiving data in return, fees for data, etc.

Weather information at UML-4 is categorized to differentiate between required and enhancing. Required data would be needed to meet weather-related performance standards. The kinds of required data would include weather information necessary for the safety of flight e.g. winds that could exceed vehicle operating capabilities and hazardous weather information. Enhancing or supplemental weather information, provided by Weather SDSPs, can exceed mandatory data requirements and standards by producing higher quality, real time data or predictions that could be incorporated with DSTs to recommend energy efficient vehicle routing or alerts to commuters of weather impacts that could impact either their trip to or from work. Another example of a DST would be to utilize the impact of weather conditions on sound to plan the route of a vehicle to remain within or below noise ordinances. In addition to the data performance standards, and data being correlated with its generating sensor, methods have been developed to continually monitor the data to identify potentially malfunctioning sensors or other issues that would impact the data's quality. Data quality for requirements considered a framework based on based a risk-based, JARUS-type approach.

4.3.6.4 Modeling and Forecasting

At UML-4, higher resolution, coupled forecast models are required to capture urban wind and weather effects for safe and cost-effective high-density urban flight operations.   These models included better physics to capture local climatic regimes over short distances, coupled atmospheric and computational fluid dynamics models to better capture wind eddies and turbulence in city canyons, machine learning techniques, etc. These models have benefited from higher density weather measurements, to improve the predictive models and to validate the models, access to high-end computing (HEC) capabilities and the contributions of government, academic non-profit and private sector research. Like the process to continually assess vehicle capabilities against potential hazards, forecasting models will continually improve as data sensors get better, HEC becomes better and more accessible and because of academic breakthroughs.

4.3.6.5 Weather Supplemental Data Service Providers (SDSPs)

The Weather Supplemental Data Service Provider (SDSP) is an integral component of the Unmanned Aircraft System (UAS) Service Supplier (SS) support ecosystem established in FAA UAS Traffic Management (UTM) ConOps, 2.0. The ULM-4 weather ConOps was build upon these principles established for weather SDSPs under this FAA UTM framework to ensure consistency with sUAS and advanced air mobility weather support and services. Below are excerpts from this ConOps:

"A weather service provides forecast and/or real-time weather information to support operational decisions of individual Operators and/or services. Weather and supplemental data sharing assists Operators with determining whether environmental conditions or other factors are suitable for flight in the intended location at the specific date and time being submitted (e.g., weather and wind prediction, planned obstacles). This data assists Operators with determining whether they can meet their responsibilities (e.g., weather, hazard/obstacles awareness) for safe flight or successfully complete their intended mission (e.g., sensor sensitivities) given the predicted conditions."

"USSs and/or SDSPs support the Operator by supplying weather, terrain, and obstacle clearance data specific to the area of operation during the pre-flight planning phase to ensure strategic management of the UTM operation as well as in-flight updates ensuring separation provision. The USS maintains and provides near real-time and forecast weather information for the region to UAS Operators. Operators monitor weather and winds throughout flight; in the event their aircraft performance is inadequate for flight in current or forecasted weather, Operators take appropriate action to safely land as soon as practical."

Weather providers include government sources and Weather SDSPs. Weather SDSPs are expected to drive innovation and leverage government and commercial weather data sets to produce granular micro-weather products and services customized to support UTM and UAM operator operations. These operations could contribute to airspace management decisions, aircraft separation and deconfliction decisions, hazardous weather detect and avoid services, operator mission data sets for take-off, landing and flight route weather optimization, etc. Weather SDSP performance standards drafted by the ASTM F38 Weather SDSP and subsequently approved by the FAA defined expected levels of data quality, reliability and SDSP performance for ULM-4. Weather SDSPs will leverage the same "raw" weather data sets as the government and have the added capability to leverage commercially acquired weather data sets and prediction models to reduce weather and wind uncertainty by providing granular hazardous weather situational awareness, predictions and DSTs products. Weather SDSPs will work on a fee-based model, like UTM SDSPs, with the goal of driving accelerated innovation and product sets to serve ULM-4 by incentivizing a private business model for UAM weather services that includes tailored services and investments in future improvements.